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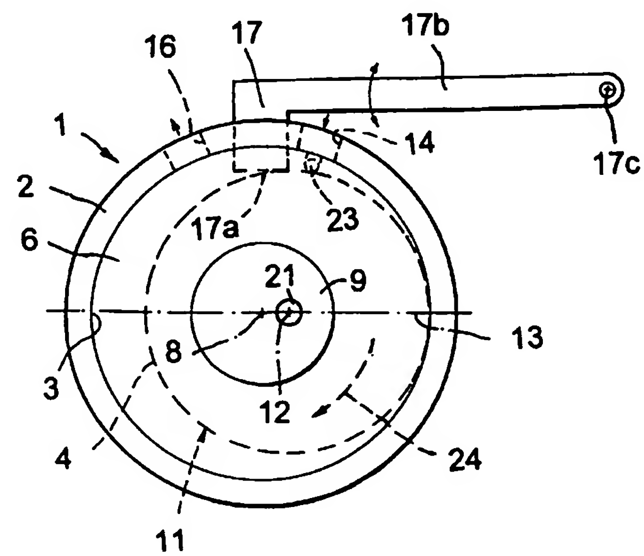
(54) Title: IMPROVEMENTS IN ROTARY POSITIVE DISPLACEMENT MACHINES



(57) Abstract: A stator (1) has a circular cylindrical internal surface (3) delimiting an operating chamber. A rotor (4) is mounted so as to be rotatable about the axis (8) of the internal surface (3) and has a cylindrical external surface (11), with one generatrix (13) adjacent to the internal surface (3), a diametrically opposite generatrix being spaced from the internal surface, A vane (18), projecting through a slot in the stator (1) into the operating chamber and being guided by a hinged member (17b), has an axial length substantially equal to that of the rotor (4). The hinged member (17b) is connected to the rotor (4) by a linkage which causes the radially inner end of the sealing member to closely follow the external surface (3). A shutter disc (6) at one end of th erotor (4) covers a port (14), in particular an inlet port, in the stator (1). The disc (6) has a through-hole with a first end remote from the operating chamber and a second end opening into the operating chamber, the first end periodically overlapping the port (14) as the rotor (4) rotates.

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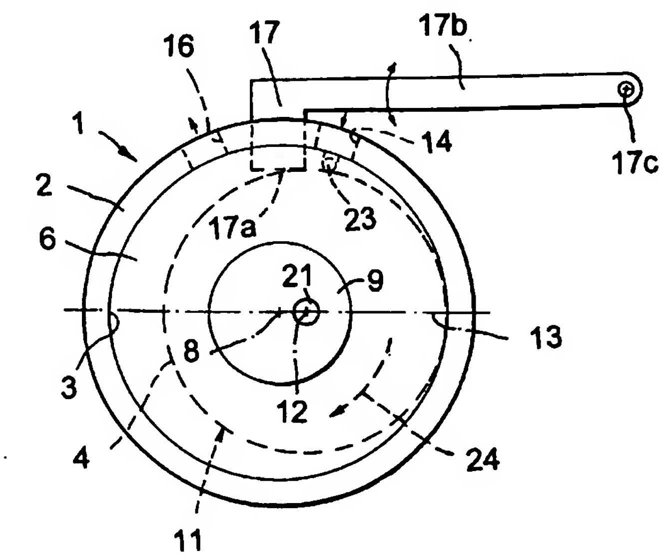


(57) Abstract: A stator (1) has a circular cylindrical internal surface (3) delimiting an operating chamber. A rotor (4) is mounted so as to be rotatable about the axis (8) of the internal surface (3) and has a cylindrical external surface (11), with one generatrix (13) adjacent to the internal surface (3), a diametrically opposite generatrix being spaced from the internal surface, A vane (18), projecting through a slot in the stator (1) into the operating chamber and being guided by a hinged member (17b), has an axial length substantially equal to that of the rotor (4). The hinged member (17b) is connected to the rotor (4) by a linkage which causes the radially inner end of the sealing member to closely follow the external surface (3). A shutter disc (6) at one end of th erotor (4) covers a port (14), in particular an inlet port, in the stator (1). The disc (6) has a through-hole with a first end remote from the operating chamber and a second end opening into the operating chamber, the first end periodically overlapping the port (14) as the rotor (4) rotates.

WO 02/04787 A2

refrigerant and oil passes through heat exchangers. The quality of the oil affects the heat transfer coefficient and the size of the passages in the heat exchangers. Oil subjected to high loads tends to degrade and increases the heat exchanger problems. When carbon dioxide is used as a refrigerant the very high pressures required by this refrigerant is a safety hazard.

In one aspect the present invention provides a rotary positive displacement machine comprising: a stator having a circular cylindrical internal surface delimiting an operating chamber; a rotor in the operating chamber, the rotor being mounted so as to be rotatable relative to the stator about the axis of the said internal surface, the rotor having a substantially cylindrical external surface, the said axis passing through the rotor, a generatrix of the external surface being adjacent to the said internal, surface, and a diametrically opposite generatrix being spaced from the said internal surface; a vane projecting outwards through a slot in the stator, the vane extending parallel to the said axis and having a length substantially equal to that of the rotor; a lever member mounted outside the stator so as to be pivotable about a pivot axis parallel to the axis of the said internal surface, the vane being integral with the lever member; and an urging mechanism which co-operates with the lever member so as to keep the radially inner end of the vane adjacent the external surface of the rotor.

The invention will be described further, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic end view of a rotary positive displacement machine, functioning as an expander, certain parts being omitted for the sake of charity.

Figure 1a is a view similar to Figure 1, showing a modified embodiment of the machine;

Figure 1b is an enlarged view taken in the direction of the arrow B in figure 1a;

Figure 2 is a perspective view of a rotary, a sealing member, and associated parts of the machine;

Figure 3 is a perspective view of the peripheral wall of a stator of the machine;

Figure 4 is a perspective view of the rotor and associated parts;

Figure 4a is a view similar to Figure 4, showing the modified embodiment;

Figure 5 is a section taken on line V-V in Figure 4;

Figure 5a is a section taken on line A-A in Figure 4a;

Figure 6 is a diagrammatic cross–section through a further embodiment of the machine; Figure 6a is a diagram corresponding to Figure 6, for explaining the effect of pressure on the vane;

Figure 6b is a diagram similar to Figure 6a, showing a modified position of the vane pivot axis;

Figure 7 is a diagrammatic end view of the further embodiment;

Figure 8 is a section taken on line VIII – VIII in Figures 6 and 7;

Figure 9 is a diagrammatic cross-section through a swinging vane rolling piston machine; and

Figure 10 is a section taken on line X – X Figure 9.

The rotary positive displacement machine illustrated has a stator or casing 1 with a peripheral wall 2 having a circular cylindrical internal surface 3. A rotor 4 arranged in the stator 1 is provided at each end with a shutter in the form of a flange or disc 6, having a circular cylindrical periphery 7 with only a small clearance between itself and the internal surface 3. The disc 6 together with the portion of the internal surface 3 extending between them delimit a circular cylindrical operating chamber in which the rotor 4 can orbit about the axis 8 of the internal surface 3. The rotor 4 is provided with trunnions 9 mounted in bearings (not shown) provided on the ends of the stator 1.

The rotor 4 has a circular cylindrical external surface 11 with an axis 12 which is accentric with respect to the axis 8 of the internal surface 3 of the stator 1. The axis 8 passes through the rotor 4. One generatrix 13 of the external surface 3, with only a small clearance. The diametrically opposite generatrix is spaced from the internal surface 3.

In the region of each disc 6 and at the same circumferential location, the stator 1 has an inlet port 14 in the form of a slot extending along a circumferential arc. In the region of the operating chamber at a circumferential location spaced from inlet ports 14, the stator 1 has an outlet port 16 in the form of an axial slot. Between the ports 14 and 16, and close to them, is a vane 17 which projects approximately radially through a slot

18 in the stator 1 so as to be freely movable towards and away from the axis 8 This motion of the vane 17 is guided by a lever member or frame 17b which is integrally fixed to the vane 17 and which is mounted outside the stator or casing 1 so as to be pivotable about an axis 17c parallel to the axis 8. The vane 17 extends parallel to axis 8 and has a length substantially equal to that of the rotor 4, with only a small clearance between the ends of the van 17 and the disc 6.

In order to keep the radially inner end 17a of the vane 17 adjacent to the external surface 11 of the rotor 4, without excessive friction, a link 19 (functioning as a connected rod) has one end articulated to a pin 21 forming an extension of the rotor 4 on a first articulation axis 21a coincident with the axis 12 and has the other end articulated to a parallel pin 22 mounted on the frame 17b and defining a second articulation axis 22a parallel to the first. In conjunction with the guiding of the vane 17 by the hinged frame 17b, this linkage (19,21,22) causes the inner end 17a of the vane 17 to closely follow the external surface 11 of the rotor 4 as it rotates about the axis 8. For balanced operation, a similar linkage may be provided on the opposite end of the machine.

The vane face loads are taken by the pivot bearing of the frame 17b and the vane tip loads can be taken by the vane actuation linkage (19,21,22). The bearings can be grease sealed and/or positioned outside the refrigerant atmosphere, therefore eliminating the need to add a lubricant. Bearings tend to have a much longer life when in an air atmosphere compared to an atmosphere created by present day refrigerants. Surfaces can be brought nearer together and therefore eliminate the need for oil sealing. Even if oil is required, degradation of the oil by friction loading is minimised.

The absence of a lubricating oil in the refrigerant provides better heat transfer and improved heat exchanger design. This is particularly useful for carbon dioxide heat exchangers, where the very high pressures require smaller passage cross-section to improve safety.

The vane 17 is wide enough to allow part of the vane tip to always be in close proximity to the rotor surface 11 at all angles of rotation. The centre of the vane tip can

therefore be positioned to provide minimum vane deflection under pressure and maximum vane end circumferential length for sealing.

The position of the vane pivot axis 17c can be made to give the minimum actuation linkage loads due to the pressure acting on the vane. A likely position for minimum vane actuation linkage loads is such that, when the vane 17 projects into the operating chamber to the maximum extent, the plane tangent to the middle of the exposed part of vane face remote from the pivot axis 17c is approximately parallel to the plane containing the axes 8,12. By selecting the actual angle (near to parallelisms) of the said tangent plane with respect to the latter plane, it can be ensured that the pressure acting on the vane always tends to urge the vane outwards (preferably) or always tends to urge the vane inwards, so that the forces acting on the linkage due to the pressure are not reversed during a cycle of rotation, the urging force in each case preferably being kept to substantially the minimum achievable.

Each disc 6 has an inlet passage or through-hole 23 with a first end 23a I the periphery 7 and a second end 23b opening into the operating chamber. Thus, the inlet port 14 only communicates with the operating chamber when the first end 23a overlaps the inlet port 14; otherwise the inlet port 14 is blanked off by the disc 6.

The above-described machine can be arranged as an expander in a heat pump (not shown) comprising a compressor, a condenser, an expander, and an evaporator, connected in series. Return vapour from the condenser is fed to the input port 14.. The circumferential length of the slots constituting the ports 14 is chosen to suit the length of time needed for the through-holes 23 to pass a required volume of vapour. Referring to Figure 1, the pressure of the vapour from the through-hole 23, acting on the rotor 4 between the vane 17 and the generatrix 13, urges the rotor 4 to turn in the direction of the arrow 24, while the vapour expands as the rotor rotates through nearly 360°. At the same time, previously expanded vapour is driven out through the outlet port 16.

The volume of fluid passing from the evaporator is seventy (70) times that returning from the condenser to the expander. As it leaves the evaporator it is a vapour and as it enters the expander it is substantially liquid. The amount of energy

recoverable is about 60 watts for every kilowatt of heat output from a heat pump. This means that, for small sizes of heat output, having a separate expander would mean no net energy recovery because the friction of the machine's bearings would probably be more than is available for recovery. For small sizes it is therefore preferable to have a machine with integral expander so there are no bearings additional to those required by the compressor.

Particularly at small sizes, the entry of the liquid needs to be as free from losses as is possible. A liquid flowing through one hole and being quickly shut off, as the hole passes by, creates a pressure wave. In Figs. 4a and 5a the entry hole 23 of Fig 4 and 5 replaced by multiple slots 23' (although these could be multiple holes). Multiple holes or slots provide easier adjustment of fluid flow and easier elimination or attenuation of pressure waves caused by the sudden shut off of fluid flow. Fluid entry could start when the slots or holes are behind the vane 17 (alongside the vane end).

Changing atmospheric temperature or machine efficiency may mean there is a need for some adjustment of the volume of fluid returning, so simple valves 15 on additional inlet ports 14a can be provided to control the system pressure as shown in Fig. 1a. The valves 15 can be actuated by any known means.

A preferred embodiment is shown in Figures 6 to 8, in which features similar to those of the above described embodiments of Figures 1 to 5 are given the same reference numerals. The description of this features will not be repeated.

In the embodiment of Figures 6 to 8 the inner end or tip 17a of the vane 17 is convex and has an axis 17d of curvature substantially coinciding with the second articulation axis 22a of the connecting rod or link 19. The vane 17 is arcuate, each of its opposite faces 17e, 17f having an axis of curvature substantially coinciding with the pivot axis 17c. The sides of the slot 18 in the peripheral wall 2 of the stator 1 are corresponding curved.

Referring to Figure 6a, the maximum inward projecting position of the vane 17 is shown in solid line and the maximum outward position (in which the vane tip 17a is fluid with the stator internal surface 3) in broken line. The fluid compressed in the

space 25 (between the internal surface 3 and the rotor 4) exerts a pressure on the vane face 17e remote from the pivot axis 17c. At maximum inward vane projection the pressure centre P_1 is near the middle of the exposed face, whereas at the outer position (broken line) the pressure centre P_2 is just inside the slot 18 in peripheral wall 2 and acts near the edge portion of the vane face 17e.

In Figure 6a the pressure forces acting on the vane tend to lift the vane off the rotor 4. The tangent T_1 to the vane face 17e at the pressure centre P_1, the tangent T_2 at the pressure centre P_2, and the mean tangent T_m are all angled in the same sense with respect to the plane V containing the axes 8,12 when the vane projects into the operating chamber to its maximum extent.

By moving the pivot axis 17c it is possible to ensure that the pressure forces acting on the vane always tend to urge the vane towards the rotor 4.

Figure 6a shows a pivot axis position in which the minimum force for both directions in found, the mean tangent T_m being parallel to the plane V. However, it will usually be preferable to have all the forces acting in one and the same direction throughout the cycle of movement of the vane 17; in order to keep the forces to a minimum in this case, either the tangent T_1 or the tangent T_2 should be parallel to the plane V.

Referring to Figure 8, the left-hand side-wall 26 could be replaced by an integral compressor disc (integral with the left-hand expander disc 6), followed by a further rotor 4, a further vane 17, and a further disc 6, to constitute a compressor.

It will be appreciated that the machine may be used as a compressor alone. Furthermore, the machine can operate on fluids other than refrigerants, e.g. vapours and gases, in particular air.

A combined compressor and expander may comprise two stators fixed end-to-end and having a common axis, and two rotors operatively connected to rotate in synchronism.

The skilled reader will appreciate that various modifications may be made within the scope of the invention. For instance, one of the discs may be omitted and the end of the stator closed off by a fixed wall delimiting one end of the operating chamber. The vane may be urged into contact with the rotor by a spring device, instead of using the linkage. The rotor could be of any suitable cylindrical shape. An outlet port ma be opened and closed by a through-hole in one of the disc in a similar way to the inlet port.

In another aspect the invention provides a rotary positive displacement machine comprising: a stator having a circular cylindrical internal surface delimiting an operating chamber; a rotor in the operating chamber, the rotor being mounted so as to orbit about the axis of the said internal surface, the rotor having a circular cylindrical external surface, the said axis passing through the rotor, a generatrix of the external surface being adjacent to the said internal surface, and a diametrically opposite generatrix being spaced from the said internal surface; a vane projecting outwards through a slot in a bushing pivotably mounted in the stator, the vane extending parallel to the said axis, having a length substantially equal to that of the rotor, and being integral with the rotor so that the vane swings as the rotor orbits; and a fluid metering mechanism which periodically admits fluid to a space defined by the vane and the said internal and external surfaces when the said space is at or near its minimum volume.

Figures 9 and 10 show a preferred embodiment of a swinging vane rolling piston machine, comprising a compressor 51 and an expander 52. The machine has a casing 53 defining a circular cylindrical compressor chamber 54 and a circular cylindrical expander chamber 55. The respective chambers 54,55 contain respective circular cylindrical rotors or pistons 56,57 with respective integral vanes 58,59, which pass through respective bushes 61 pivotably mounted in the casing 53. The cylindrical pistons 56,57 are mounted on respective accentrics 62,63 integral with a shaft 64 which is rotatably mounted in casing 53 and which has an axis 64a coinciding with the axes of the chambers 54,55. When the shaft 64 rotates, the pistons 56,57 orbit about the axis 64a. The chambers 54,55 are isolated from each other by an integral disc 66 on the shaft 64 and are isolated from the outside either by side-walls of the casing 53 or by side discs on the shaft.

In order to enable expansion energy to be recovered by the machine, fluid from the condenser of the heat pump circuit is supplied to a passageway or bore 67 in the casing 53 on the expander side. As the vane 59 swings, a passageway or bore 68 in the bush 61 of the expander 52 periodically communities between the inlet bore 67 and a passageway or recess 69 in the swing vane 59, which in turn communicates with a closed space 71 defined between the piston 57 and the internal peripheral wall of the expander chamber 55 when this space 71 is at its minimum volume. The expanding vapour exerts a force on the piston 57 which is transmitted to the piston 56 by the shaft 64.

A swing vane machine requires a mixture of oil and refrigerant in order to lubricate the bush and swinging vane that passes through its centre. The bush and passageways provide a metering mechanism to allow a swinging vane rolling piston to recover expansion energy. Because this requires additional rubbing surfaces and attendant friction losses, recovery will be less than those using the hinging vane described previously. A greater efficiency and flexibility of size will be provide if metering the return fluid is provided by one or more side disc and a metering hole, as above (e.g. with reference to Fig.4a and 5a), instead of passing through the bush.

CLAIMS:

1. A rotary positive displacement machine comprising:

a stator having a circular cylindrical internal surface delimiting an operating chamber;

a rotor in the operating chamber, the rotor being mounted so as to be rotatable relative to the stator about the axis of the said internal surface, the rotor having a substantially cylindrical external surface, the said axis passing through the rotor, a generatrix of the external surface being adjacent to the said internal, surface, and a diametrically opposite generatrix being spaced from the said internal surface;

a vane projecting outwards through a slot in the stator, the vane extending parallel to the said axis and having a length substantially equal to that of the rotor;

a lever member mounted outside the stator so as to be pivotable about a pivot axis parallel to the axis of the said internal surface, the vane being integral with the lever member; and

an urging mechanism which co-operates with the lever member so as to keep the radially inner end of the vane adjacent the external surface of the rotor.

2. A rotary positive displacement machine as claimed in claim 1, in which the pivot axis is positioned such that the forces acting on the vane due to pressure in the operating chamber are minimal and are directed either always towards or always away from the rotor.

3. A rotary positive displacement machine as claimed in claim 1 or 2, in which the urging mechanism comprises a linkage which connects the lever member to the rotor so as to cause the radially inner end of the vane to closely follow the external surface of the rotor.

4. A rotary positive displacement machine or claimed in claim 3, in which the linkage comprises a link having one end articulated to an extension of the rotor on a first articulation axis coincident with the axis of the said external surface, being a circular cylindrical surface, and the other end articulated to the lever member on a second articulation axis parallel to the first.

5. A rotary positive displacement machine or claimed in claim 4, in which the radially inner end of the vane is convex and has an axis of curvature substantially coinciding with the second articulation axis.

6. A rotary positive displacement machine as claimed in any preceding claim, which the vane is arcuate, each of its opposite faces having an axis of curvature substantially coinciding with the pivot axis.

7. A rotary positive displacement machine as claimed in any of claims 1 to 6, in which when the vane projects into the operating chamber to its maximum extent, a plane tangent to the middle of the exposed part of the vane face remote from the pivot axis is substantially parallel to the plane containing the said axis of the said internal surface and the central axis of the rotor.

8. A rotary positive displacement machine as claimed in any of claim 1 to 6, in which when the vane projects into the stator to its minimum extent, a plane tangent to an edge region of the vane face remote from the pivot axis is substantially parallel to the plane containing the said axis of the said internal surface and the central axis of the rotor.

9. A rotary positive displacement machine as claimed in any preceding claim, further comprising a shutter at one end of the rotor, the shutter rotating with the rotor and covering a port in the stator, the shutter having a passage with a first end remote from the operating chamber and a second end opening into the operating chamber, the first end periodically overlapping the port as the rotor rotates relative to the stator.

10. A rotary positive displacement machine as claimed in claim 9, in which the shutter is in the form of a disc.

11. A rotary positive displacement machine as claimed in claim 10, in which the first end of the passage is in the periphery of the disc.

12. A rotary positive displacement machine as claimed in claim 11, in which the passage is in the form of a slot open at the periphery and the inner face of the disc.

13. A rotary positive displacement machine as claimed in any of claims 9 to 12, in which there are a plurality of said passages arranged successively in the circumferential direction.

14. A rotary positive displacement machine as claimed in any of claims 9 to 13, in which there are a plurality of said ports arranged successively in the circumferential direction.

15. A rotary positive displacement machine as claimed in any of claim 9 to 14, in which the port or at least one said port is provided with a valve.

16. A heat pump comprising a compressor, a condenser, an expander, and an evaporator, connected in series, in which the compressor comprises a rotary positive displacement machine according to any of claims 1 to 15.

17. A heat pump comprising a compressor, a condenser, an expander, and an evaporator, connected in series, in which the expander comprises a rotary positive displacement machine according to any of claim 1 to 15.

18. A combined compressor and expander, comprising respective rotary positive displacement machines according to any of claims 1 to 15, the stators of the two machines being fixed end-to-end and having a common axis, and the rotors of the two machines being operatively connected to rotate in synchronism.

19. A rotary positive displacement machine comprising:

a stator having a circular cylindrical internal surface delimiting an operating chamber;

a rotor in the operating chamber, the rotor being mounted so as to orbit about the axis of the said internal surface, the rotor having a circular cylindrical external surface, the said axis passing through the rotor, a generatrix of the external surface being adjacent to the said internal surface, and a diametrically opposite generatrix being spaced from the said internal surface;

a vane projecting outwards through a slot in a bushing pivotably mounted in the stator, the vane extending parallel to the said axis, having a length substantially equal to that of the rotor, and being integral with the rotor so that the vane swings as the rotor orbits; and

a fluid metering mechanism which periodically admits fluid to a space defined by the vane and the said internal and external surfaces when the said space is at or near its minimum volume.

20. A rotary positive displacement machine as claimed in claim 19, in which the fluid metering mechanism comprises a first passageway in the stator, a second passageway in the bush, and a third passageway in the vane, the second and third passageways periodically providing communication between the first passageway and the said space as the vane swings relative to the stator.

21. A rotary positive displacement machine as claimed in claim 19, in which the fluid metering mechanism comprises a shutter at one end of the rotor, the shutter rotating with the rotor and covering a port in the stator, the shutter having a passage with a first end remote from the operating chamber and a second end opening into the operating chamber, the first end periodically overlapping the port as the rotor rotates relative to the stator.

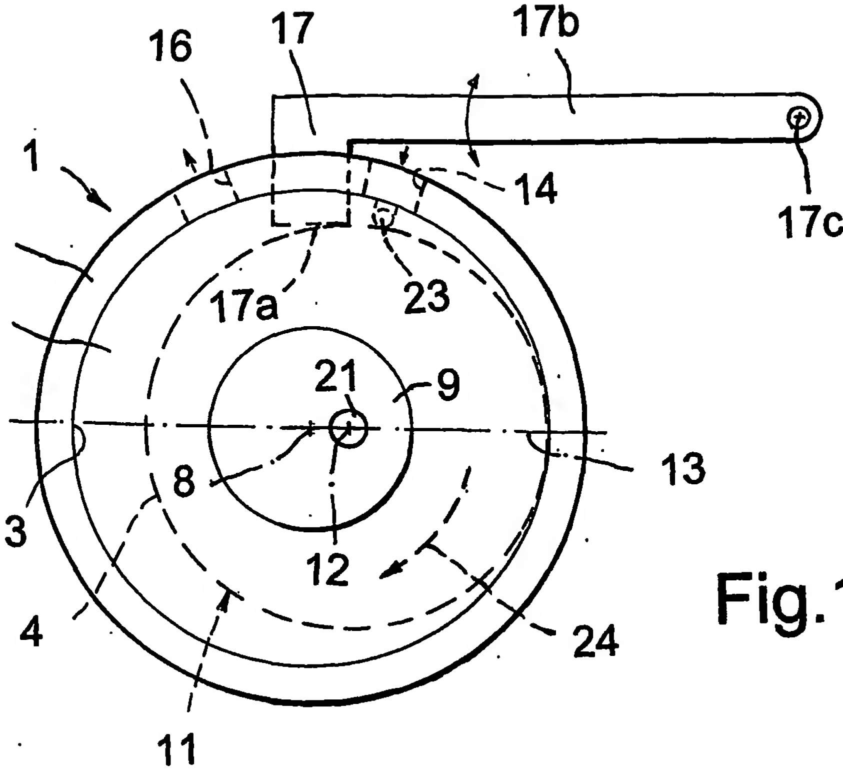


Fig.1

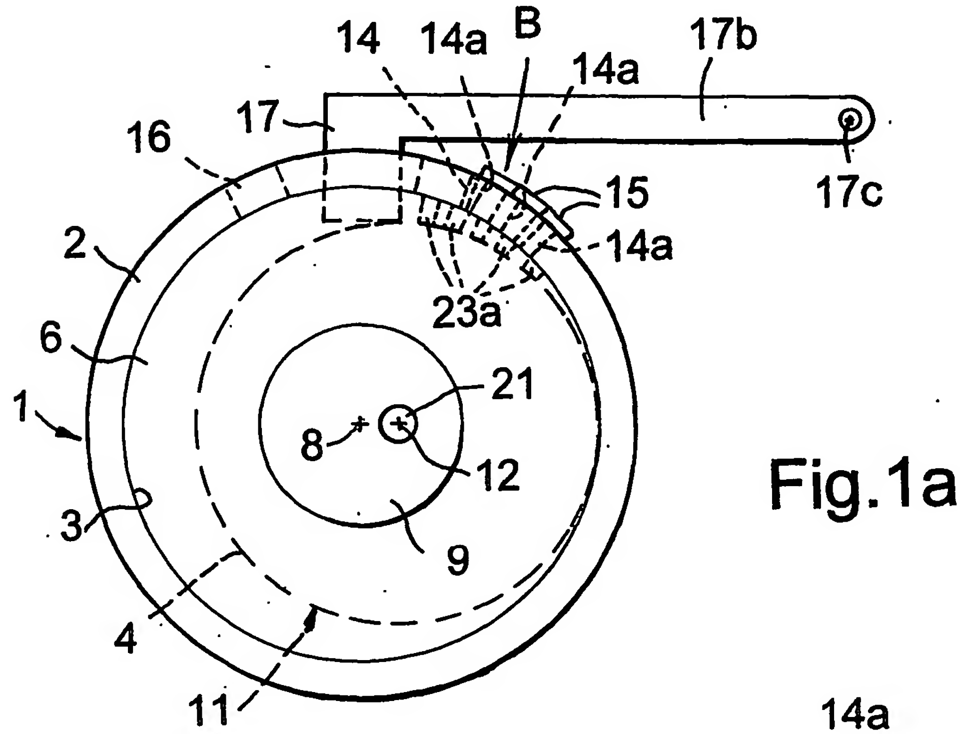
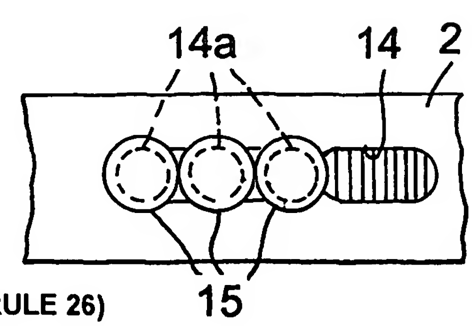


Fig.1a

Fig.1b



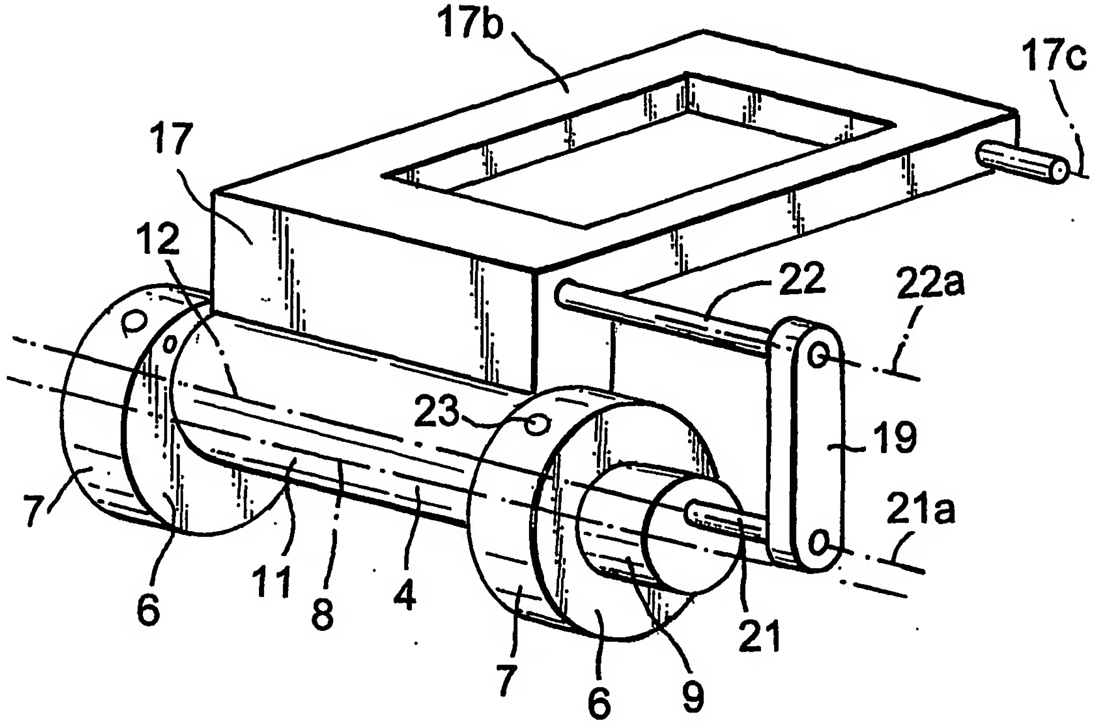


Fig.2

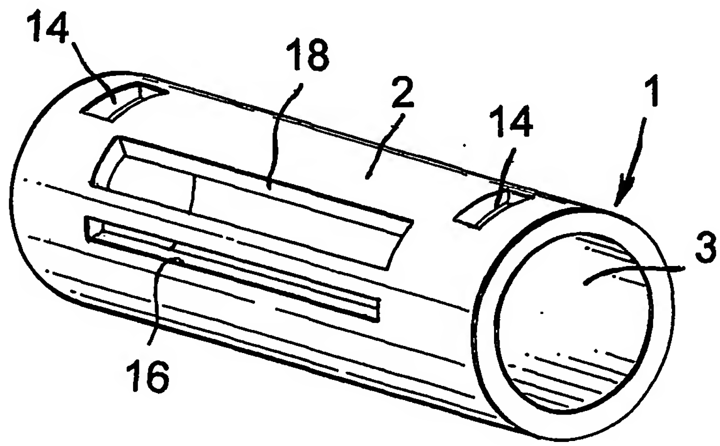


Fig.3

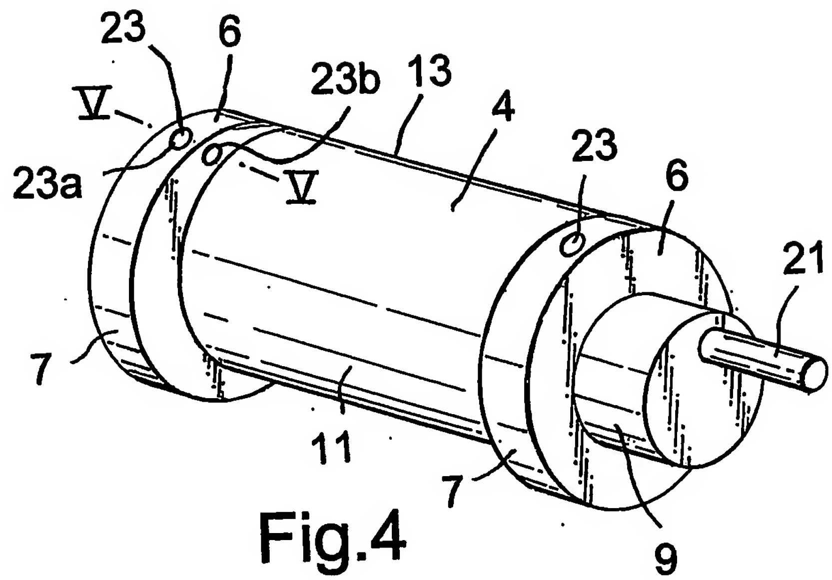


Fig.4

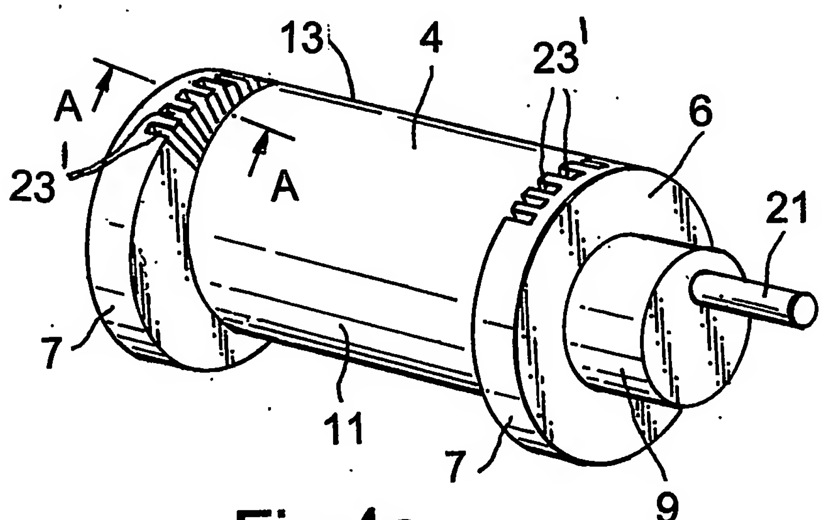


Fig.4a

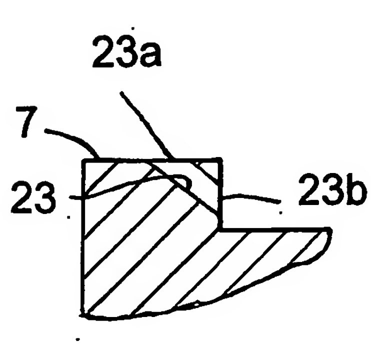


Fig.5

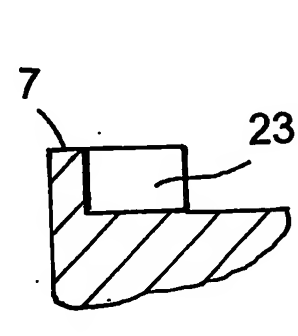
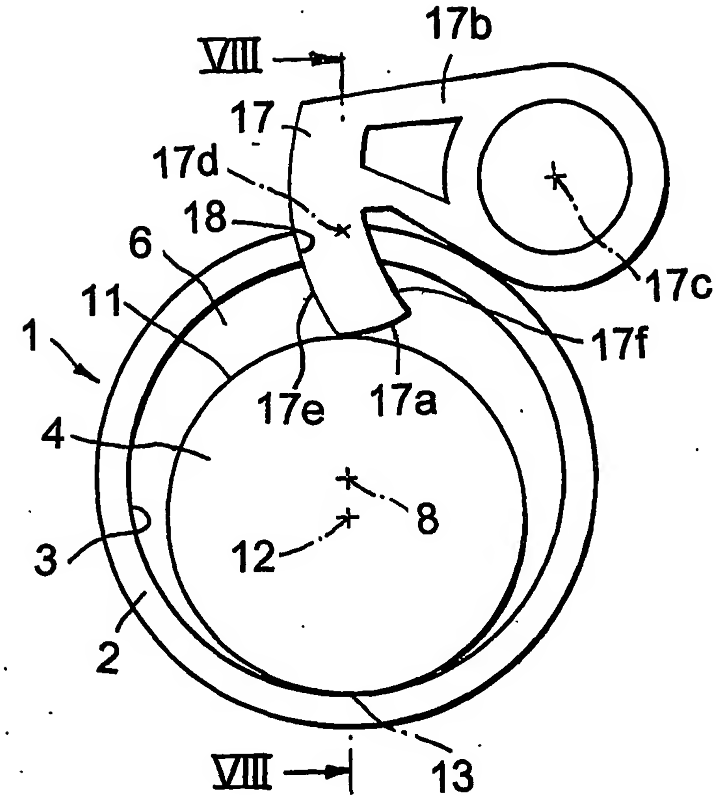
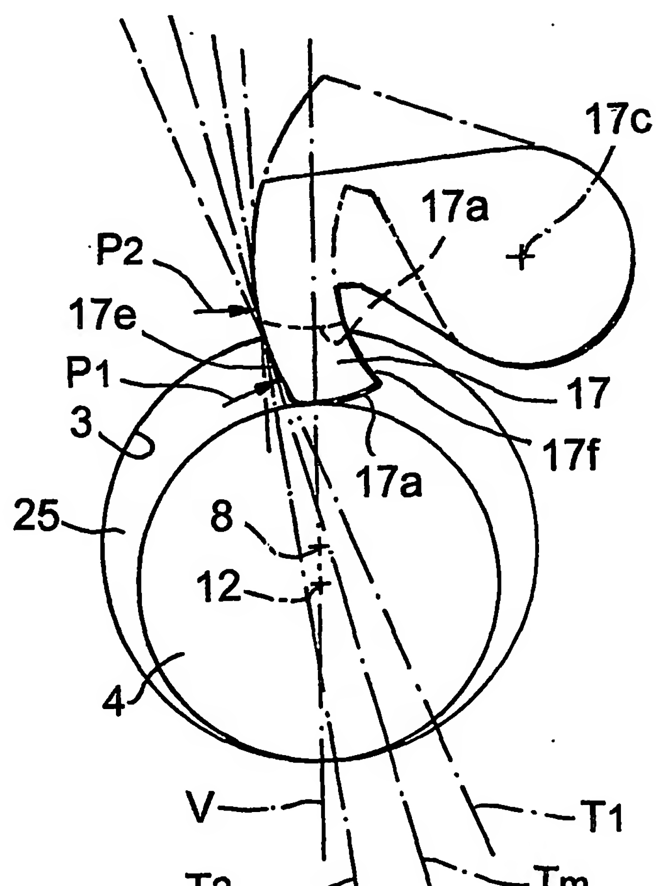


Fig.5a



17b
VIII
17
17d
18
6
11
1
4
3
2
17c
17f
17e
17a
8
12
13
VIII

Fig.6



17c
17a
P2
17e
P1
3
25
17
17f
17a
8
12
4
V
T1
T2
Tm

Fig.6a

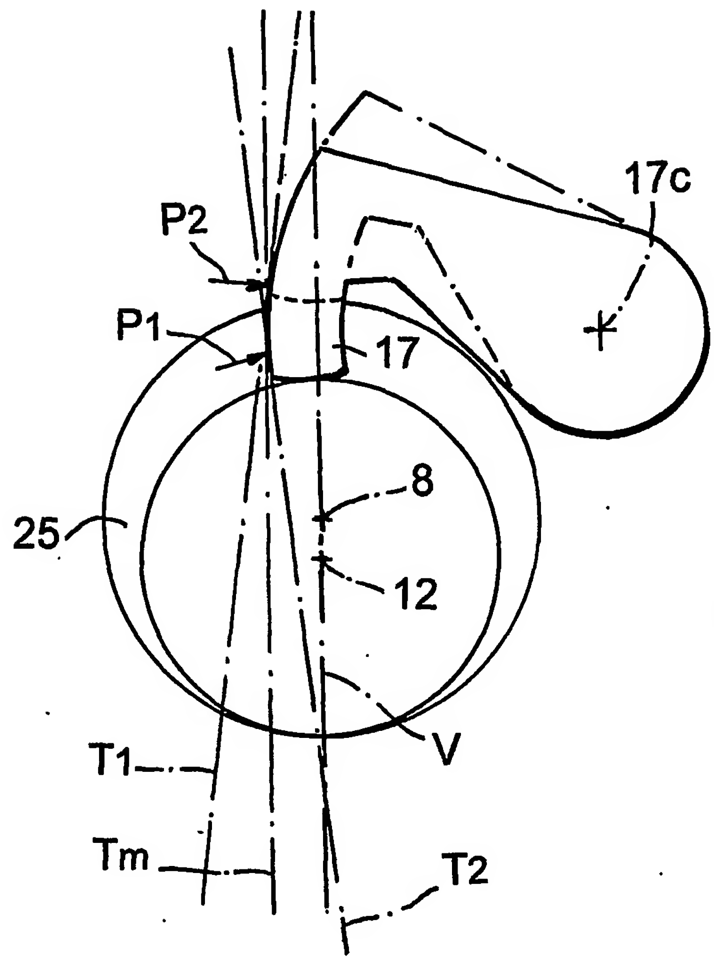

17c
P2
P1
17
8
25
12
T1
V
Tm
T2

Fig.6b

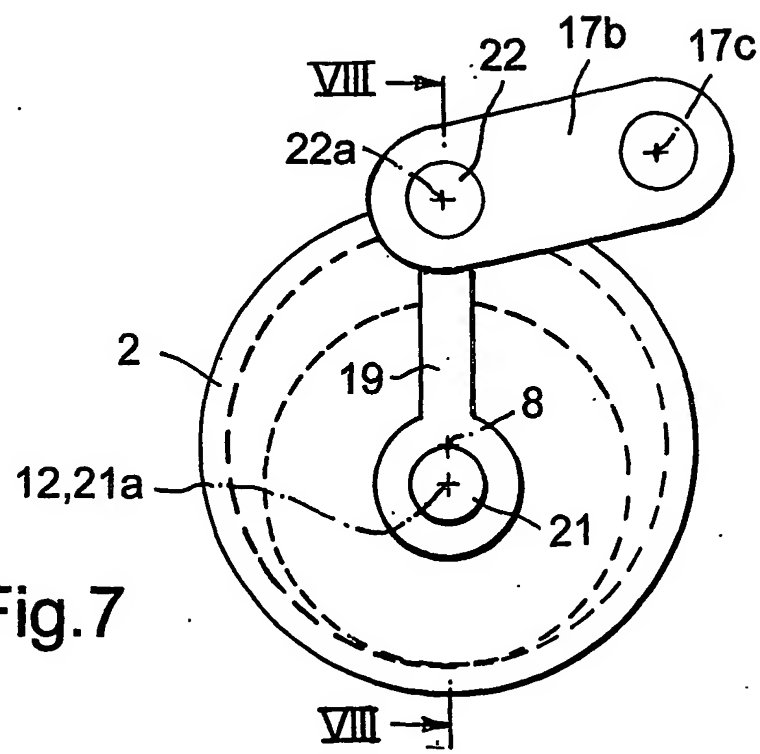

VIII
22
17b
17c
22a
2
19
8
12,21a
21
VIII

Fig.7

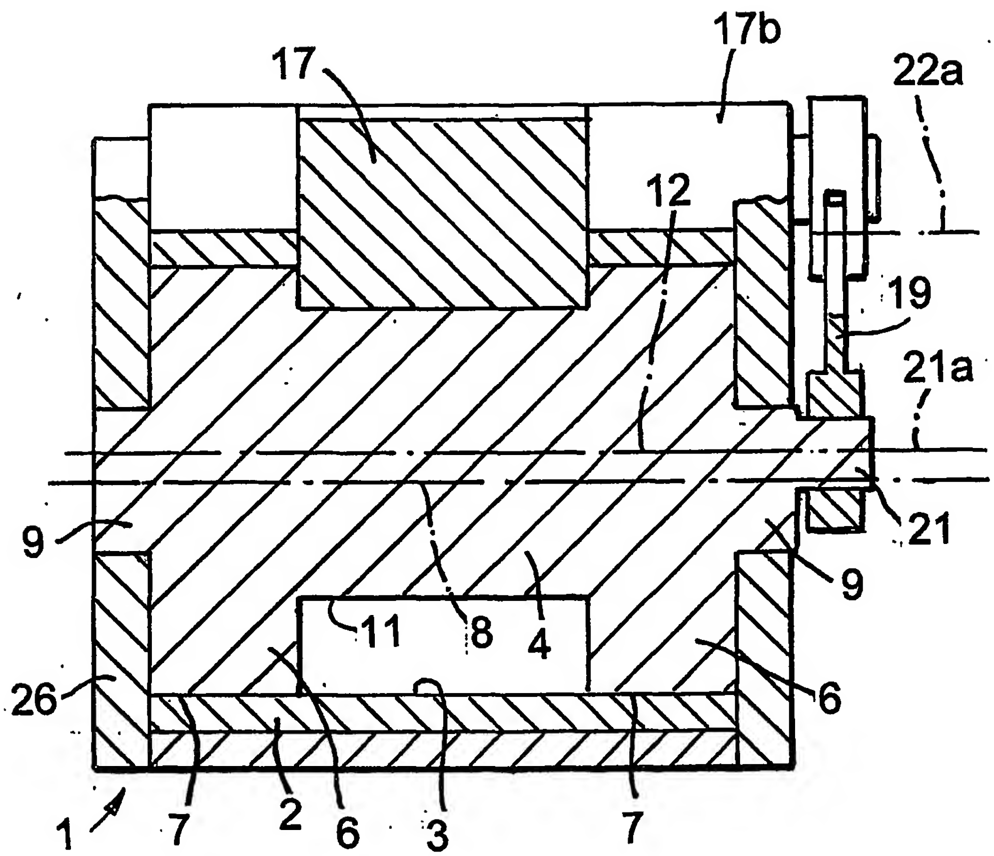


Fig.8

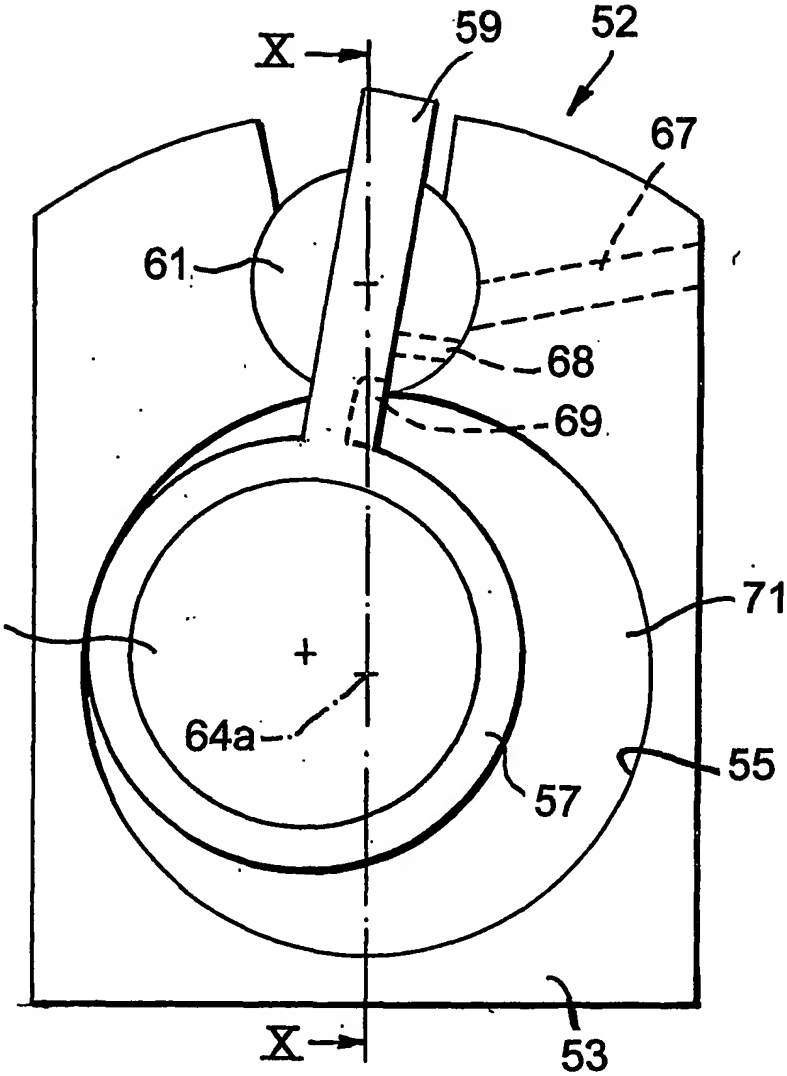


Fig.9

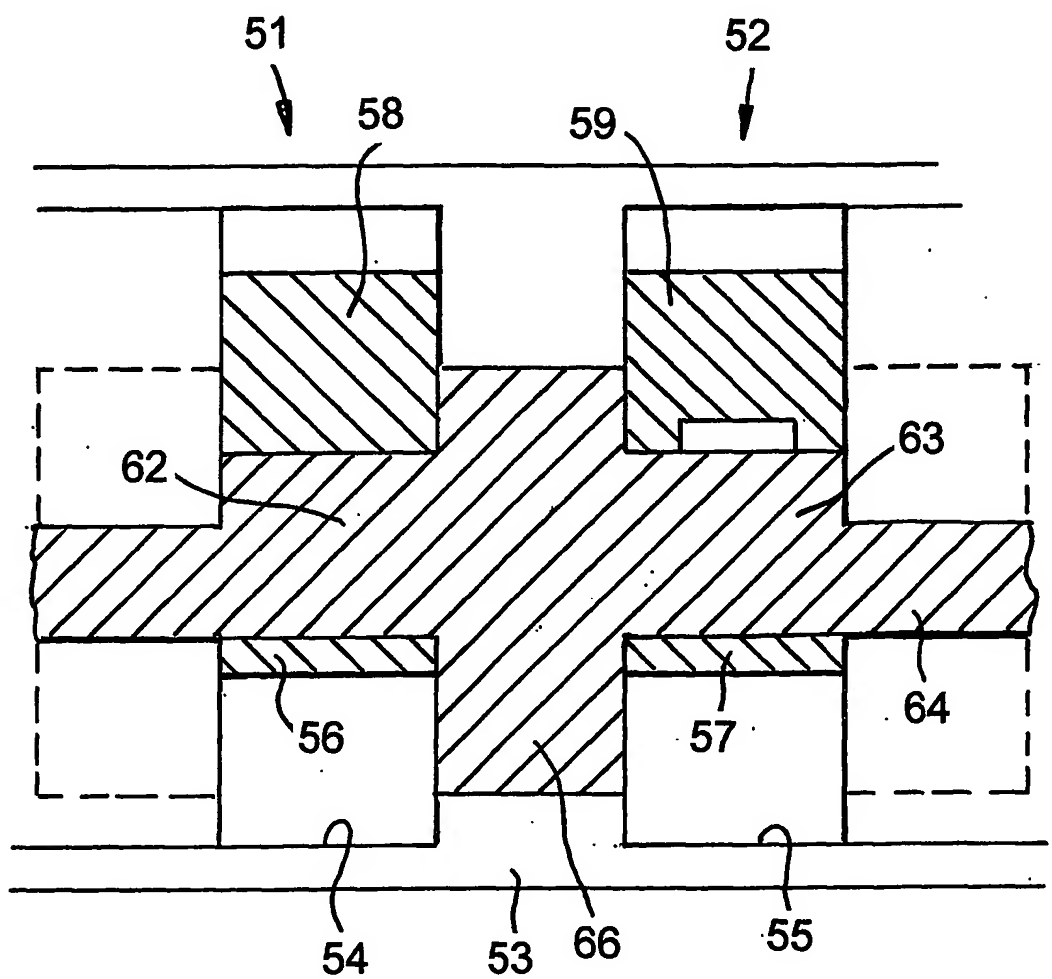


Fig.10